

## WHAT IS CLAIMED IS:

1. A method to remove a contrast agent injected into the blood of a patient using an extracorporeal circuit having at least a withdrawal conduit, a filter, an infusion conduit and a filter by-pass conduit, wherein said method comprises:

a. positioning a withdrawal catheter into or proximate to a chamber of the heart of the patient;

b. withdrawing blood from the chamber into the withdrawal catheter and to the withdrawal conduit of the extracorporeal circuit;

c. routing blood from the withdrawal conduit through the filter by-pass conduit and to the infusion conduit to infuse the blood into the patient, and

d. after contrast agent is injected into the blood flow of the patient, routing substantially all of the blood flowing through the withdrawal conduit to the filter and then to the infusion conduit to infuse the filtered blood into the patient, wherein the filter substantially removes the contrast agent from the withdrawn blood.

2. A method as in claim 1 wherein step (d) includes detecting the contrast agent in the blood flowing through the extracorporeal circuit with a contrast detector coupled to the circuit.

3. A method as in claim 1 wherein step (d) includes automatically routing substantially all blood from the withdrawal conduit through the filter for a period from the injection of the contrast agent and for a pre-determined period following termination of the injection of the contrast agent.

4. A method as in claim 1 wherein step (d) includes substantially ceasing pumping by a by-pass pump coupled to the by-pass conduit and starting pumping by a filter pump coupled to a section of the withdrawal conduit upstream of the filter and downstream of a connection between the withdrawal conduit and by-pass conduit.

5. A method as in claim 1 wherein a withdrawal pump regulates a rate of blood flow through the withdrawal conduit and a by-pass pump regulates a rate of blood flow through the by-pass conduit.

6. A method as in claim 5 wherein a controller for the extracorporeal circuit controls the withdrawal pump and the by-pass pump, and said controller substantially stops said by-pass pump to direct flow through the filter after the contrast agent has been injected.

7. A method as in claim 1 further comprising introducing a blood supplementation fluid to the blood flow passing through the filter, wherein said supplementation fluid replaces a volume of blood substantially similar to a volume of filtrate removed by the filter.

8. A method as in claim 7, wherein a rate of introduction of said supplementation fluid is regulated by a supplementation pump.

9. A method as in claim 7, wherein a controller determines the volume of filtrate removed by the filter and adjusts the supplementation pump to provide the rate of introduction of said supplementation fluid.

10. A method as in claim 1 wherein the blood is withdrawn continuously from the chamber of the heart and the withdrawal catheter substantially blocks an outlet of the chamber of the heart during the withdrawal of blood in steps (c) and (d).

11. A method as in claim 1 wherein the blood is withdrawn continuously from the chamber of the heart and the withdrawal catheter substantially blocks an outlet of the chamber of the heart during the withdrawal of blood, wherein the withdrawal catheter includes a balloon at a distal end of the catheter and wherein said balloon remains inflated as the contrast agent is injected into the patient.

12. A method as in claim 11 wherein the balloon remains inflated until the contrast agent is substantially removed by the filter.

13. A method to remove a contrast agent injected into the blood of a patient using an extracorporeal blood circuit having at least one withdrawal pump, a filter and a controller, wherein said method comprises:

- a. inserting a withdrawal catheter into or proximate to a chamber of the heart of the patient;
- b. withdrawing blood from the chamber into a withdrawal catheter;
- c. detecting the contrast agent in the blood flow through the extracorporeal blood circuit,
- d. inhibiting an injection of additional contrast agent into the blood while the contrast agent is detected in the blood flowing through the circuit;
- e. filtering the blood with the filter to remove the contrast agent from the blood, and
- f. infusing filtered blood into the patient.

14. A method as in claim 13 further comprising initiating withdrawal of the blood after injection of the contrast agent and before detection of the contrast agent in the blood circuit.

15. A method as in claim 13 wherein inhibiting the injection is performed by an alarm issued to the operator of an injector for the contrast agent.

16. A method as in claim 13 wherein inhibiting the injection is performed by automatically interrupting an injector for the contrast agent.

17. A method as in claim 13 wherein said method is performed during an angiographic or coronary intervention procedure.

18. A method as in claim 13 wherein the chamber of the heart into which the withdrawal catheter is inserted is a coronary sinus.

19. A method to assist in the removal of a contrast agent injected into the blood of a patient using an extracorporeal blood circuit having at least one withdrawal pump, a filter and a controller, wherein said method comprises:

- a. inserting a withdrawal catheter in or proximate to a chamber of the heart of the patient;
- b. withdrawing blood from the chamber into the withdrawal catheter;
- c. passing the withdrawn blood through the blood circuit;
- d. filtering the contrast agent from the blood through the filter;
- e. infusing filtered blood into the patient, and

f. automatically regulating a rate of withdrawal of the blood from the chamber based on a withdrawal pressure and a desired withdrawal pressure as determined by the controller.

20. A method as in claim 19 wherein the controller determines whether the withdrawal pressure

21. A method as in claim 19 wherein automatically regulating the rate further comprises reducing the blood flow being withdrawn from the chamber when a withdrawal pressure of the blood in the circuit becomes more negative than an occlusion limit that is a function of blood flow through the circuit, and

if the reduced blood flow is reduced below a predetermined minimal flow, then temporarily reversing the withdrawal of blood from the chamber and infusing blood through the withdrawal catheter into the chamber of the heart.

22. A method as in claim 19 wherein the withdrawal blood flow is gradually reduced as a function of flow rate.

23. An extracorporeal blood circuit comprising:

a withdrawal conduit connectable to a coronary withdrawal catheter;

a withdrawal pump connectable to the withdrawal conduit, wherein a pumping rate of the withdrawal pump determines a blood withdrawal rate from the coronary withdrawal catheter;

a filter having an input connected to the withdrawal conduit and a blood output connected to an infusion conduit and a filtrate output connected to a filtrate conduit;

a filtrate measurement device to determine an amount of filtrate removed from the blood in the filter;

a fluid supplementation conduit providing a blood replacement fluid to at least one of the withdrawal conduit, filter and infusion conduit;

a supplementation pump connectable to the fluid supplementation conduit, wherein a pumping rate of the supplementation pump determines a rate at which the blood replacement fluid flows into the blood flowing through the blood circuit, and

a controller regulating the pumping rate of the supplementation pump such that the rate of the blood replacement fluid provides an amount of blood replacement fluid to the at least one of the withdrawal conduit, filter and infusion conduit so as to substantially match the amount of filtrate removed.

24. An extracorporeal blood circuit as in claim 23 wherein the filtrate measurement device is a weight scale connectable to a filtrate collection bag.

25. An extracorporeal blood circuit comprising:

a withdrawal conduit connectable to a coronary withdrawal catheter;

a withdrawal pump connectable to the withdrawal conduit, wherein a pumping rate of the withdrawal pump determines a blood withdrawal rate from the coronary withdrawal catheter;

a filter having an input connected to the withdrawal conduit and a blood output connected to an infusion conduit and a filtrate output connected to a filtrate conduit;

a by-pass conduit coupled to the withdrawal conduit at a position upstream of the filter and said by-pass conduit also coupled to the infusion conduit, wherein a by-pass pump connectable to the by-pass conduit determines a blood flow rate through the by-pass conduit, and

a controller regulating the pumping rate of the by-pass pump such the blood flow rate through the by-pass conduit is substantially zero while a contrast agent is in the blood.

26. An apparatus as in claim 25 further comprising a contrast agent detector on the extracorporeal circuit, wherein said detector issues a signal to the controller when the contrast agent is detected in the blood flowing through the circuit.

27. An apparatus as in claim 25 wherein the contrast agent detector is a hemocrit sensor.

28. An apparatus as in claim 25 further comprising a filter blood pump connectable to the withdrawal conduit downstream of a connection between the by-pass conduit and withdrawal conduit.

29. An apparatus as in claim 28 wherein the controller further regulates the filter blood pump such that the filter blood pump is stopped when the by-pass pump is moving blood through the by-pass conduit, and the by-pass pump is stopped when the filter blood pump is moving blood through the filter.

30. An apparatus as in claim 28 wherein the controller further regulates the filter blood pump such that the filter blood pump moves blood from the filter and in an upstream direction through the withdrawal conduit when the by-pass pump is moving blood through the by-pass conduit, and the

by-pass pump is stopped when the filter blood pump is moving blood downstream through the withdrawal conduit and to the filter.

31. An extracorporeal blood circuit comprising:

a withdrawal conduit connectable to a coronary withdrawal catheter;

a withdrawal pump connectable to the withdrawal conduit, wherein a pumping rate of the withdrawal pump determines a blood withdrawal rate from the coronary withdrawal catheter;

a filter having an input connected to the withdrawal conduit and a blood output connected to a filtered blood reservoir and a filtrate output connected to a filtrate conduit;

a by-pass conduit coupled to the withdrawal conduit at a position upstream of the filter and said by-pass conduit also coupled to the infusion conduit, wherein a by-pass pump connectable to the by-pass conduit determines a blood flow rate through the by-pass conduit, and

a controller regulating a pumping rate of the by-pass pump such the blood flow rate through the by-pass conduit is substantially zero while a contrast agent is in the blood and wherein said controller regulates a pumping rate of the withdrawal pump to draw blood with contrast agent through the filter and to subsequently reverse the flow of blood through the filter to draw filtered blood from the reservoir and into the by-pass conduit.

32. A circuit as in claim 31 further comprising a supplementation pump connectable to a fluid supplementation conduit, wherein a pumping rate of the supplementation pump determines a rate at which replacement fluid flows into the blood flowing through the blood circuit, and said controller



further regulates the pumping rate of the supplementation pump such that the rate of the replacement fluid provides an amount of blood replacement fluid to the at least one of the withdrawal conduit, filter and infusion conduit so as to substantially match the amount of filtrate removed.

33. A method for removing a contrast agent using an extracorporeal blood circuit having a blood withdrawal pump, a by-pass pump, and a filter, said method comprising:

- a. withdrawing blood from a coronary withdrawal catheter positioned to draw substantially all blood flowing from a chamber of a heart of a patient such that the withdrawn blood flows into a withdrawal conduit;
- b. infusing the withdrawn blood into the patient via a by-pass conduit and infusion conduit without treating the blood;
- c. injecting a contrast agent into a blood vessel of the patient such that the contrast agent flows with blood into the chamber of the heart;
- d. after injecting the contrast agent, temporarily ceasing blood flow through the by-pass conduit and directing the blood withdrawn from the chamber through the filter, wherein the filter extracts the contrast agent from the blood, and
- e. infusing filtered blood into the patient.

34. A method as in claim 33 wherein during step (d) the blood flow through the filter is temporarily collected in a reservoir and step (e) comprises moving blood from the reservoir through filter to be infused into the patient.

35. A method as in claim 33 wherein during step (e) the filtered blood flows from the reservoir through the filter and the by-pass conduit before being infused into the patient.